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TO
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THE EFFECTS OF THREE-DIMENSIONAL IMPOSED DISTURBANCES ON BLUFF BODY NEAR WAKE FLOWS

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Imposed 3-D Disturbances on Bluff-Body Near Wake Flows

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PROJECT ABSTRACT

Research Goals:

We wish to achieve a better understanding of the underlying three-dimensional flow structure in the near wake of a bluff body when subjected to imposed geometrical disturbances. We want to understand the effects of three dimensionality that are characterized by vortex splitting and looping and how they are related to other wake parameters such as base pressure shedding frequency, wake width and wake formation length.

Objectives:

To obtain a fundamental understanding of the three-dimensional features that arise in the near wake flow region behind nominally two-dimensional bluff bodies with mild three-dimensional disturbances such as a sinusoidal-trailing edge blunt based section body (BB) and a circular cylinder with a spanwise periodic trailing edge splitter plate affixed (CC).

Approach:

To investigate the three-dimensional structure of bluff body near wakes at high Reynolds wind tunnel and water channel experiments were carried out at both institutions (U. of Notre Dame and Imperial College). Measurements of velocity fluctuations and pressures as well as flow visualization experiments have been carried out to reveal the three-dimensional effects present in the wake.

Tasks Completed:

For the BB body with a mild periodic geometric spanwise disturbance:

- Velocity fluctuations and pressure have been measured.

- Flow visualization experiments have been performed to observe the shedding patterns from the sinusoidal trailing edge body and compared to those observations from a straight-trailing-edge model.

- A model for the dynamics of the formation region has been proposed.

- A study of the various modes of vortex shedding that occur behind the wavy trailing edge model has been performed a video showing all three-dimensional features has been prepared.

For the CC body with spanwise periodic splitter plates:

- Simultaneous base pressure along the span of the cylinder for different ℓ/D's and varying wavelength have been measured and correlated to hot-wire measurements in the near wake.

- Water channel flow visualizations for several splitter plate configurations using the electrolytic precipitation method have been completed and a video of the experiments has been prepared.

- The energy distribution for spanwise periodic trailing edge splitter plates has been mapped in the near wake at Re=30,000 and compared to two-dimensional splitter plate results for $\ell/D<1$.

Results:

For the BB body measurement of the fluctuating velocity and pressure, as well as flow visualization, have revealed the existence of a dual shedding frequency. The two frequencies are most apparent close to the peak in the trailing edge (a position where the chord of the model is greatest), whereas at a valley only the higher of the two frequencies is observed. The flow adjusts between regions of different shedding frequency by forming a vortex dislocation. Base drag is lowest at a peak and is everywhere lower than that measured behind a straight-trailing-edge model. Vortex dislocations are also observed to occur behind the straight trailing edge model but they appear to happen at random points along the span and at random time intervals.

A careful study has been made of the various vortex mode of vortex shedding that occur behind the wavy-trailing-edge model. Four three-dimensional patterns of vortex shedding have been observed and these are shown diagrammatically in figure 1. The shedding frequency f_1 that occurs close to the peak is lower than the second frequency f_2. In the symmetric mode shedding in adjacent valleys is in phase and it is out of phase in the antisymmetric mode. In the symmetric mode a cell of lower frequency is situated in the region of a peak and dislocations occur on either side. These dislocations occur at a frequency equal to the difference between the two vortex shedding frequencies. Two dislocations are also seen in the 3-cell antisymmetric mode, whereas in the 2-cell antisymmetric mode one dislocation region occurs at a peak separating two regions of the same frequency but different phase. In water tunnel experiments a high frequency oblique mode of shedding was also seen but it is not clear if this was present at the higher Reynolds numbers of the wind tunnel experiments.

Flow visualization experiments for the CC body in the water channel using the electrolytic precipitation method have clearly indicated several modes of shedding and strong three dimensionality that include vortex looping and vortex dislocations. It was found that for certain ℓ/D's, for those below the minimum drag condition, the shedding

pattern became very regular and two-dimensional in spite the geometrically imposed three dimensionality in the near wake. A map of the energy distribution in the wake at several downstream locations indicated a strong correlation between the maximum disturbance energy in the near wake and the regular two-dimensional shedding patterns observed for some splitter plates of $\ell/D < 1$. Selective spanwise trailing-edge-splitter plates are seen to be effective in reducing three-dimensional effects in the near wake.

Accomplishments:

1. Demonstration of several shedding modes in the flow behind a bluff body with geometrically imposed three-dimensionality.

2. We have found that the introduction of mild geometric three-dimensionality can control the positions of vortex splitting as well as the energy distribution in the near wake

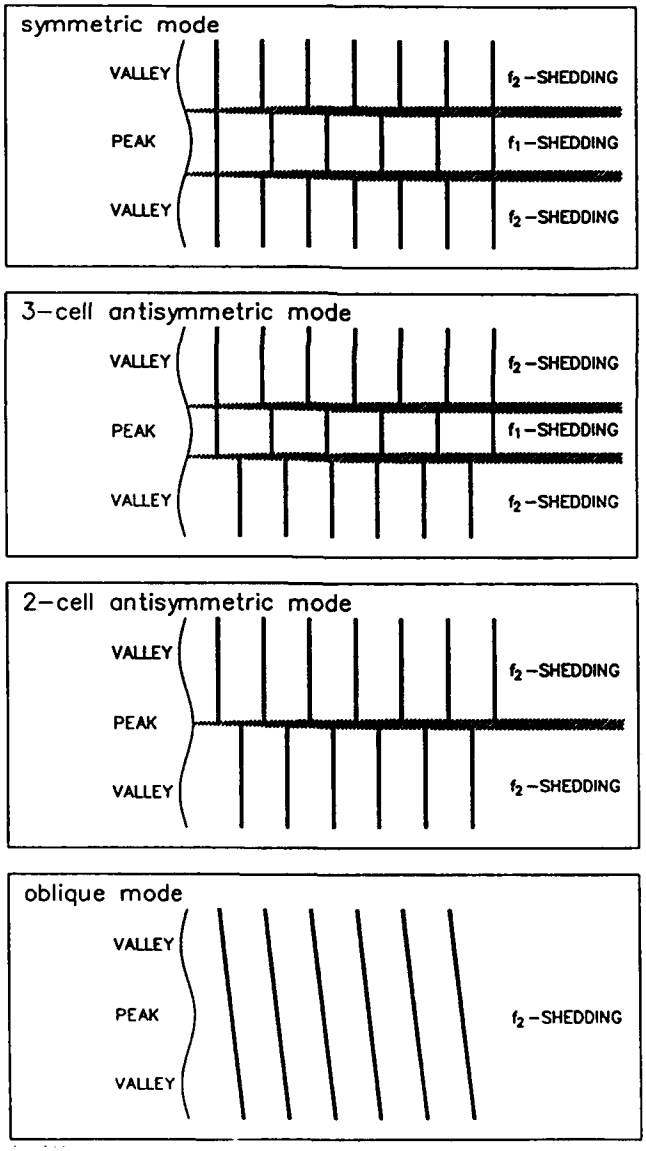

FIGURE 1. SCHEMATIC DIAGRAM OF DIFFERENT SHEDDING MODES

PUBLICATIONS FROM ONR SPONSORED WORK - FY91/FY92
Professor Albin A. Szewczyk
Professor Peter W. Bearman
December 1992

91 - C Szewczyk, A. A., Bearman, P. W. and Tombazis, N., Effect of Imposed Three-Dimensionality on Flows Past Bluff Bodies. Amer. Phys. Soc. Bull. Vol. 36, No. 10. p. 2656, Nov. 1991.

91 - C Szewczyk, A. A., and Bearman, P. W., Effects of 3-D Imposed Disturbances on Bluff Body Near Wake Flows. Presentation at ONR Workshop, Tempe, AZ, Mar. 1991.

92 - C Bearman, P. W., Effects of 3-D Imposed Disturbances on Bluff Body Near Wake Flows. Presentation at ONR Workshop on Wake Vortex Dynamics, Columbus, Ohio, May 1992.

92 - C Szewczyk, A. A., Effects of 3-D Imposed Disturbances on Bluff Body Near Wake Flows. Presentation at ONR Workshop on Wake Vortex Dynamics, Columbus, Ohio, May 1992.

92 - IC Bearman, P. W., Challenging Problems in Bluff-Body Wakes. Invited paper IUTAM Symposium on Bluff-Body Wakes, Dynamics and Instabilities, Göttingen, Sept. 1992.

92 - P,C Borg, J. and Szewczyk, A. A., Unsteady Base Pressure Measurements in the Near Wake of a Cylinder with Imposed Three-Dimensional Disturbances. Accepted for publication, to appear in IUTAM Proc. Bluff-Body Wakes, Dynamics and Instabilities, Springer-Verlag, Göttingen, Sept. 1992.

92 - C Szewczyk, A. A. and Anderson, E., Some 3-D vs. 2-D Effects of Splitter Plate on the Near Wake Flow of a Circular Cylinder. Amer. Phys. Soc. Bull. Vol. 37, No. 8, p.1747, November 1992.

92 - P Pearson, L. and Szewczyk, A. A., The Near-Wake of a Circular Cylinder with a Spanwise Periodic Trailing Edge Splitter Plate. FED-Vol. 138/PVP-Vol. 245, ASME Proc. Inter. Symp. Flow-Induced Vibration and Noise, Vol. 6, pp 75-86, November 1992.

92 - C Bearman, P. W. and Tombazis, N., The Effects of Three-Dimensional Imposed Disturbances on Bluff Body Near Wake Flows. Second International Colloquium on Bluff Body Aerodynamics and Applications, Melbourne, December 1992.

92 - R Pearson, L., On Imposed Three-Dimensional Disturbances in the Near Wake of Circular Cylinder. M. S. Thesis, U. of Notre Dame, May 1992.

PUBLICATIONS CONTINUED

92 - R Borg, J., Unsteady Base Pressure Measurements on a Bluff Body with Imposed Three Dimensionality. M S. Thesis, U. of Notre Dame, Aug. 1992.

92 - R Tombazis, N., Effects of Three-Dimensional Disturbances on Bluff Body Near Wakes. Ph.D. Thesis, Imperial College, University of London, Nov. 1992.

Enclosure (2)

OFFICE OF NAVAL RESEARCH
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT
1 Oct 91 through 30 Sep 92

R&T Number: 421g012---01

Contract/Grant Number: N00014-90-J-4083

Contract/Grant Title: The Effect of Three-Dimensional Imposed Disturbances on Bluff Body Near Wake Flows

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a. Number of Papers Submitted to Referred Journal but not yet published: 2

b. Number of Papers Published in Refereed Journals: 2 (list attached)

c. Number of Books or Chapters Submitted but not yet Published: 0

d. Number of Books or Chapters Published: 0 (list attached)

e. Number of Printed Technical Reports and Non-Refereed Papers: 4 (list attached)

f. Number of Patents Filed: 0

g. Number of Patents Granted: 0 (list attached)

h. Number of Invited Presentations at Workshops or Prof. Society Meetings: 1

i. Number of Presentations at Workshops or Prof. Society Meetings: 6

j. Honors/Awards/Prizes for Contracts/Grant Employees: 0
(list attached, this might include Scientific Soc. Awards/ Offices, Promotions/Faculty Awards/Offices, etc.)

k. Total Number of Graduate Students and Post-Docs Supported at least 25% this year on this contract/grant:

Grad Students 4 and Post-Docs 0 including
Grad Student Female 1 and Post-Docs Female 0.
Grad Student Minority 0 and Post-Doc Minority 0.

Minorities include Blacks, Aleuts, AmIndians, Hispanics, etc.
NB: Asians are not considered an under-represented of minority group in science and engineering.

Enclosure (3)